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formulated in the tribal rites, wherein was set forth, with unmistakable clearness, to the people, the importance of the perpetuation of human life upon the earth, and, of the recognition, that the life-giving power of Wakonda is ever present in all things that surround man.

THE MECHANISM OF ANTAGONISTIC SALT ACTION

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1. The work on antagonistic salt action has shown that we must discriminate between two distinct groups of such phenomena. The first group is represented by the counteraction of the toxic effects of a salt with a univalent cation by a salt with a bivalent cation. I showed in 1901 that all salts with a univalent cation rapidly kill the newly fertilized eggs of the marine fish *Fundulus* when the concentration of these salts exceeds a certain limit, while the addition of a very small (though definite) quantity of a large number of salts with a bivalent cation prevents or retards this injurious action.[1] Salts with bivalent anions had no such effect. The rôle of the valency of the cation in these phenomena of antagonism was unmistakable and was pointed out in the same papers as was also the relation to certain rules in the precipitation of colloids, but it was not possible to indicate an antagonistic action on colloids between salts with univalent and bivalent cations. I suggested later that the rapid death of the eggs in the salts with univalent cations was due to a diffusion of the salts into the eggs, while the addition of the salt with a bivalent cation prevents or retards this rapid diffusion,[2] and this suggestion was supported by later experiments.

It therefore appeared from these observations that the salts with monovalent cations increase the permeability of the membrane when their concentration exceeds a certain limit, and that the addition of a trace of a salt with a bivalent cation, e.g., $CaCl_2$, diminishes the permeability. This idea received support in the floating experiment of the writer with *Fundulus* eggs[3] and in Osterhout's experiments on the galvanic resistance of *Laminaria* in NaCl and $CaCl_2$ solutions.[4]

The second group of antagonistic phenomena is represented by the following experiments. In 1911 Loeb and Wasteneys found that a KCl solution in the concentration in which this salt is contained in the sea water is toxic for the marine fish *Fundulus*, while the addition of NaCl in a definite ratio (17 molecules or more of NaCl to 1 molecule of KCl) annihilates the toxic effect of KCl. Na_2SO_4 was about twice as efficient for this purpose as NaCl.[5] I showed later that the poisonous effects of NaBr, $NaNO_3$, and other salts, could also be annihilated by the addition of NaCl[6] and the same was found to be true for the effect of acids.[7] Since a pure solution of NaCl does not diminish but increases the permeability of the membrane it was not possible to explain these cases on the assumption of an opposite influence of the antagonistic electrolytes upon the permeability of the cell wall. I have recently made some experiments in collaboration with Mr. McKeen Cattell which have led me to a theory which seems also to furnish the physico-chemical analogue to this second group of phenomena of antagonism.

We found that the same concentration of KCl in distilled water causes the standstill of the heart of the embryo much more quickly than when contained in sea water. This experiment (which we will call experiment I) is simply a confirmation of the previous experiments of Loeb and Wasteneys on the adult fish, and it might be interpreted on the assumption that the permeability of the membrane for KCl is greater in distilled water than in sea water. But this explanation of experiment I is rendered impossible by experiment II which follows. Eggs were exposed to a KCl solution until the heart stopped beating. They were then equally distributed in distilled water and in sea water and it was observed in which of the two solutions the hearts began to beat first. The result was very striking. While the hearts of the eggs in the sea water began to beat again in a few hours, or in less than a day, those in distilled water often did not recover in a number of days. When their recovery failed to occur within reasonable time in distilled water the heart beat could be called forth in less than a day by transferring the eggs to sea water.

The recovery of the hearts poisoned with KCl depends upon the diffusing out of the KCl from the egg. If it is legitimate to assume in experiment I that in distilled water the KCl causes the heart to stop more quickly because the membrane is more permeable for KCl in distilled water than in sea water, we should expect that in the recovery experiment the hearts would also begin to beat sooner in distilled water than in sea water; since in the latter the membrane is assumed to be less permeable than in distilled water. Hence in sea water it should require more time for the excess of KCl to diffuse out of the egg than in distilled water, which is the reverse of what we observed. It is, therefore, impossible to explain these observations on the assumption that in distilled water the permeability of the cell membrane for KCl is greater than in sea water.

3. We next tried whether other substances acted like sea water, and

found that a great number of salts could replace sea water in the two above mentioned experiments. Thus m/2 NaCl or m/2 LiCl or $NaNO_3$ or many other salts retarded the poisoning effect of KCl upon the heart of the embryo and accelerated the recovery about as much as did sea water. We are, therefore, dealing here with a general salt action which increases in certain limits with the concentration of the salt and which varies for different salts. Thus it was found that for equal concentrations the citrates are much more efficient than the sulphates or tartrates and these are more efficient than the chlorides or nitrates; which indicates a valency effect of the anion.

A trace of acid when added to distilled water may also accelerate the recovery of the hearts poisoned with KCl. Bases have no such effect. Sugar solutions act like distilled water.

4. The question arises: How is it possible for salts (or acids) to retard the entrance of KCl into the egg or to facilitate the diffusion of KCl out of an egg which has been poisoned with this salt? All previous theories of antagonistic salt action (with the exception of the one proposed by Loeb and Wasteneys for the case of KCl and NaCl) have only considered three quantities: the concentration C_{I} of the poisonous salt (in our case KCl) in the outside solution, the concentration C_{II} of the injurious salt inside the membrane, and the "permeability" of the membrane. I am of the opinion that it is necessary to introduce another quantity, namely the concentration C_{III} of the poisonous salt at the boundary between the membrane and the outside solution. I assume, therefore, that there are forces at work (chemical or kindred) between the membrane and the poisonous salt in the surrounding solution (e.g., KCl) whereby this salt adheres or is attached to the external surface of the membrane in a concentration C_{III} which is different from C_{I}; and that C_{III} and not C_{I} determines the rate at which the salt diffuses into the egg. It is further assumed that the presence of other salts influences the (chemical or kindred) forces acting on the surface of the membrane whereby the concentration C_{III} at the surface of the egg is different from what it would be if the injurious salt (e.g., KCl) were alone in solution. *Whenever the influence of another salt is such as to diminish* C_{III} *we are dealing with a case of antagonistic salt action.*

5. In order to test this idea the writer made experiments in which he substituted a dye, namely neutral red, for KCl. He found that in the same concentration of neutral red the eggs of *Fundulus* are stained red more rapidly if the dye is contained in distilled water than in a salt solution or in a solution containing acid. He found, moreover, that the more dilute the solution of a given salt the less its antagonistic effect to

neutral red; and that sulphates inhibit the staining of the egg more powerfully than equal concentrations of chlorides. The same agencies which prevent or retard the entrance of KCl into the egg of *Fundulus* prevent or retard the staining of the membrane with neutral red.

If we stain eggs of *Fundulus* in neutral red and put them afterwards into distilled water or salt solutions free from stain, the eggs will be decolorized rapidly in salt solutions or in acid solutions, while they will be decolorized very slowly in distilled water. The decoloration occurs the more rapidly the higher the concentration of the salt, and more rapidly in sulphates than in chlorides.

The antagonism between the staining effect of neutral red upon the eggs of *Fundulus* and salts or acids is, therefore, parallel to that between the injurious effect of KCl upon the same eggs and salts or acids. In the case of neutral red we can see directly that the salt or acid diminishes the concentration C_{III} of the neutral red on the surface of the egg. When an egg stained in neutral red is put into a m/2 solution of NaCl or of NaCl + $CaCl_2$ or a m/8 solution of Na_2SO_4 streaks of the dye are seen to stream from the surface of the egg into the surrounding solution, while nothing of this kind occurs if the eggs are put into H_2O. Here we can ascertain by direct observation that the antagonistic action of the salt on the dye consists in diminishing the concentration C_{III} of the dye on the external surface of the membrane. The diminution of C_{III} on the external surface of the membrane diminishes the rate with which the dye diffuses into the egg and accelerates the rate with which the dye can diffuse out of the egg.

If it is legitimate to apply this reasoning to the explanation of the second group of cases of antagonistic salt action, the observed facts on the antagonism between KCl and other salts or acids could be expressed as follows: In distilled water the attractive forces acting between the outer surface of the membrane of the egg and KCl are very strong and hence the concentration C_{III} of this salt at the outer surface of the membrane reaches a high value; while these forces of attraction between KCl and the outer membrane are diminished when salts or acids are added to the outer medium in the proper concentration. This explains why the recovery of the embryo poisoned in KCl is very slow when the egg is put into distilled water, since in this case the concentration of the KCl (or other K salts) at the outer surface of the membrane remains very high and thus prevents the diffusion of KCl from the interior of the egg into the distilled water; while if a salt in a sufficiently high concentration is added to the distilled water the value C_{III} of KCl on the outside surface of the membrane is diminished and the barrier to the diffusion of the KCl from the interior of the egg to the outside solution is removed.

This theory holds probably for all cases of the second group of phenomena of antagonism, namely where salts (and possibly acids) in general antagonize the injurious action of an electrolyte. It must remain for further investigations to decide whether it holds also for the first group of cases of antagonism where the injurious action of high concentrations of a salt with a monovalent cation (e.g., NaCl) is inhibited by traces of a salt with a bivalent cation (e.g., $CaCl_2$). The two groups of phenomena are in one respect the converse of each other, since in the first group the efficiency of the antagonistic action increases with the valency of the cation, while in the second group the antagonistic action increases with the valency of the anion of the antagonistic salt.

[1] Loeb, *Archiv ges. Physiol., Bonn,* **88**, 68 (1901); *Amer. J. Physiol.,* **6**, 411 (1902).

[2] Loeb, *Archiv ges. Physiol. Bonn,* **107**, 252 (1905).

[3] Loeb, *Biochem. Zs.,* **47**, 127 (1912).

[4] Osterhout, *Science,* **35**, 112 (1912); *Bot. Gaz., Chicago,* **59**, 317 (1915).

[5] Loeb and Wasteneys, *Biochem. Zs.,* **31**, 450 (1911).

[6] Loeb, *Ibid.,* **43**, 181 (1912).

[7] Loeb and Wasteneys, *Ibid.,* **33**, 489 (1911); **39**, 167 (1912).

THE NITROGEN PROBLEM IN ARID SOILS

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Standing eminent, if not preëminent, everywhere, in considerations of soil fertility, the nitrogen problem is especially so under arid soil conditions. The acuteness of the situation in the latter has been recognized, however, by neither the scientist nor the practical man until recently when certain investigations on the one hand, and certain field manifestations on the other, have caused to stand out in sharp relief the nitrogen question from among others in California's soil puzzles. It is with reference to some of these recent findings, and their bearing on problems of soil fertility in California, that this brief paper is written as a forerunner of more detailed discussions soon to appear elsewhere.[1]

Considering only the average nitrogen-content of California soils, as based on a thousand or more analyses, the student of the subject does not obtain a true picture of the paucity in nitrogen which characterizes our truly arid soils. For many of our soils are situated in regions of heavy winter rainfall and produce a luxuriant spring growth;